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Mekhanizatsiya Stroitel'stva, No 1, 1952.SOVIET DIESELS FOR CONSTRUCTION AND ROAD MACHINES

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 Cand Tech Sci

The growing output of construction and road machines calls for a great quantity of engines of various types, especially Diesel engines. The constantly growing demand for Diesels is not being met quantitatively or qualitatively, since Diesels specially designed for use in construction and road machines are not being produced at present. As a result, engines designed for other applications are now being installed on construction and road machines with unsatisfactory results.

The GAZ-MK and U-5M combine gasoline engine and the IMA automobile and tractor kerosene engine used in construction are unsatisfactory, both in the type of fuels they require and in their operating characteristics, reliability, and reserve motor resources.

D-6 and YaAZ-204 Diesels are not acceptable because they lack motor resources, general strength, and reliability in their design.

The KIM-46 Diesel is unsatisfactory in many instances because of its overall dimensions and total weight. The engine is particularly unsuitable for the E-505 excavator.

The D-35 and D-53 Diesels are most acceptable for some construction and road machines, however, their rated revolutions per minute exceed the speeds required for these machines. Moreover, these engines are not unified and require different spare parts and different replaceable filter elements for repair and servicing. In addition, these engines are in such short supply that the production of construction machines based on them is constantly threatened with disruption because of nondelivery of engines.

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These circumstances often force the planning of construction and road machines based on the parameters of engines currently being produced, instead of basing them on technical, economic, and operating considerations promoting the greatest specific productivity of the machines, their profitableness, length of service, and reliability.

For example, all type-sizes of road rollers are put out with GAZ-MK and U-5M gasoline engines, which raises the cost of the work performed by the rollers, and consumes a great quantity of passenger car fuel. These same U-5M and GAZ-MK are installed on rock crushers, excavators, asphalt pavers, and other machines. It is perfectly obvious that these small, light gasoline engines are used, not because they fulfill the design requirements of the machines mentioned, but because the necessary Diesels are lacking.

Attempts to use the costly D-6 Diesel on excavators and other machines doing heavy duty work at sharply changing speeds and under conditions of severe vibration lead to rapid wear and breakage of the engines.

Replacing internal combustion engines with electric motors deprives the machine of its mobility, restricting it to the vicinity of the electric power line.

The great variety of engine types used on road and construction machines, not unified with respect to parts and components and requiring different types of fuel, make repair, servicing, and supply of spare parts and operating materials to the construction projects extremely complex and expensive under the semifield conditions existing at the construction sites.

The scope of construction mechanization has increased to the point where it has become necessary to build Diesels meeting the requirements and operating conditions of construction and road machines.

In 1948, the design and scientific research connected with the development of Diesels for construction and road machines was started in the power-engineering laboratory of VNIISTroydormash (All-Union Scientific Research Institute of Construction and Road Machine Building).

On the basis of a study of design and operating conditions of different types of construction and road machines, a series of Diesels with rated horsepower capable of fulfilling the requirements of the overwhelming majority of construction machines currently being produced was established. In outlining this group of Diesels, machines whose planning and production are scheduled in the next 5-10 years are taken into account. Table 1 gives the parameters, covering the range from 14 to 360 horsepower of the projected Diesels, and their applications. The basic principle guiding the development of this series of unified Diesels was to have the greatest possible number of parts in common and the smallest possible number of type-sizes of Diesels.

In conformity with this principle, a group of Diesels was developed all having the same cylinder diameter of 125 millimeters and the same stroke of 170 millimeters, but having varying numbers of pistons. Horsepower is adjusted to the needs of particular machines by setting the governor to the required number of revolutions per minute within the limits of 1,000 to 1,500 revolutions per minute. The average calculated number of revolutions per minute was set at 1,200. The horsepower of individual engines can be increased by enlarging the cylinder, within the limits defined by the fixed distances between cylinder axes in the design adopted.

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This projected series permits the assembly of engines with varying numbers of cylinders out of the greatest possible proportion of identical parts.

Maximum interchangeability of parts makes it possible to organize their production by the constant-flow method, thus reducing the cost of the engines and making possible the profitable use of special machine tool equipment and technological processes which raise the quality of the finished engines. This applies particularly to cylinder sleeves, pistons, piston rings, piston pins, connecting rods, valves, valve mechanism parts, and the fuel apparatus.

With identical basic dimensions of the piston stroke and cylinder bore, crankshaft journals, distance between cylinders, shape of the camshaft cams and location of the cams on the camshaft, it is possible to machine blocks with different numbers of cylinders, crankshafts with different numbers of cranks, camshafts, and cylinder heads on the same specialized machine tools using the same tools, profiling devices, and setup, provided that these machine tools are planned or purchased so that they can machine the longest part required. Thus for example, the machine tools for milling or grinding the cams of camshafts set up for milling camshafts for the six-cylinder engine can be used to mill or grind the shafts for all the remaining Diesels with a smaller number of cylinders without complex resetting of the machine tool, since the profiling devices do not change and remain at the same distances from each other.

The following basic design parameters were adopted for the whole series of Diesels.

The rated number of revolutions per minute was one of the most important parameters, defining in turn the means of forming the mixture, the fuel consumption, specific power, weight indexes, over-all dimensions of the Diesel, its reliability, and length of service.

In selecting the rotation speed of the engine, the following factors, derived from the design of currently produced construction and road machines and from operating experience, were kept in mind.

1. Alterations necessitated by the installation of the new Diesels, especially in the transmission and working parts, should be held to a minimum.
2. The rotation speed selected should assure reliable operation of the Diesel without repair for no less than 2,000 to 3,000 hours.
3. A number of machines should be put out powered either by an alternating current electric motor or by Diesel, with the remark "close to 1,000 and 1,500 revolutions per minute, or with Diesels." In this way, replacement of the electric motor by a Diesel can be carried out without major alterations of the transmission, that is, kinematic interchangeability between electric motors and Diesels should be observed. Based on these and other considerations, the three rated figures of 1,000, 1,200, 1,500 revolutions per minute were selected, facilitating the corresponding settings of the governors.

Mixing the fuel in a precombustion chamber was selected because it meets the requirements of Diesels for construction and road machines. Mixing the fuel in a precombustion chamber produces low maximum ignition pressure, a gradual rise in pressure, enables the Diesel to operate on low-quality fuel, and makes it possible to use low-pressure fuel injection with low sensitivity to the quality of atomization. This, in turn, makes it possible to use a relatively simple, cheap, and reliable fuel apparatus, and also makes it possible to operate with constant advance of fuel feed into the cylinder, and gives good response to sharply changing working loads.

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All these factors make the precombustion chamber Diesel highly economical, wear resistant, and less sensitive to fuel quality.

The mean effective pressure, characterizing the efficiency of the Diesel's working process in the calculations, was set at 6.25 kilograms per square centimeter, the same as in the KDM-46 Diesel, which also has precombustion chamber and a rated rotation speed of 1,000 revolutions per minute.

The choice of this figure also reflects the tendency to limit the strain in Diesels and lengthen their lives. The mean effective pressure chosen is higher than that of other USSR automobile and tractor Diesels and is sufficiently high for the given type of engine, demanding careful design and technological development of the Diesel.

Table 2 gives comparative parameters characterizing the operating process and the basic design indexes of the proposed series of Diesels and also of existing tractor Diesels. The comparison shows that the indexes of the proposed Diesels represent a step forward.

Table 3, which gives comparative weight and over-all size indexes, shows that only the one-cylinder Diesel has specific weight indexes (specific weight and liter weight) inferior to those of the tractor Diesels; this is natural for a one-cylinder engine (which has a heavy flywheel) compared to a multi-cylinder engine. The two-cylinder engine has better weight indexes than the D-54 engine (which has four cylinders), but does not meet the performance of the D-35 and KDM-46 engines. The three-cylinder Diesel and all the other Diesels of the series have better weight indexes than the tractor Diesels.

In over-all dimensions, the Diesels for construction machines are superior to the tractor Diesels in length; there are no significant differences in height and width.

In choosing the starting system, the special operating and storage conditions of construction machines were kept in mind. As a rule, these machines operate in open areas, in various geographic latitudes, primarily in regions with relatively low average yearly temperatures.

The most important problem in starting a Diesel is to warm up the fluid in the cooling-system, the oil in the crankcase and oil lines, the air entering the cylinders, the oil film on mating parts, and also, of starting the circulation of oil through all oil lines and openings. Next, the Diesel's crankshaft must be given enough speed to start the engine.

Gasoline engine starting has proved the best solution to the requirements listed above, and was chosen for this series of Diesels. The exhaust gases of the starting motor are used to warm up the intake manifold of the Diesel and the heat from its cylinder walls is used to warm up the liquid in the Diesel's cooling system. The oil in the Diesel is warmed up by preliminary turning-over of the engine with the compression shut off.

The series of Diesels for construction and road machines have the following design features.

The crankcase is a one-piece tunnel-type rigid casting (with nonremovable oil pan for the one-, two-, and three-cylinder engines) with large side hatches for removing connecting rods and pistons from the engine and carrying out assembly operations in the engine.

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The pistons are made of aluminum alloy and have four compression rings and one oil ring. The piston head is hollowed out to form the main combustion chamber. The form of this cavity in the piston head corresponds to the form of the stream of gases escaping from the precombustion chamber as the fuel is ignited. The piston pin is of the full-floating type.

The connecting rods are drop forged, with an oblique joint on the lower end which makes it possible to insert the rod into the engine through the top of the cylinder.

The crankshafts of all the engines are mounted in the crankcase on anti-friction bearings. The shafts of the one-, two-, and three cylinder engines are one-piece forgings and each is mounted on two bearings. The shafts of all the remaining engines are detachable and mounted on the full number of supports.

The valves are in the head and have two springs each. To prevent local wear of the valve stems and the tips of the valve rocker, the valve spring retainer locks are hardened to a high degree.

The camshafts have intake and exhaust cams of the same shape. They are mounted on antifriction bearings, and driven by timing gears.

The intake and exhaust manifolds are separate and are mounted on opposite sides of the cylinder head. The intake manifold is equipped with heating jackets through which the exhaust gases from the starting motor pass. Before entering the intake manifold, the air is cleaned of dust in a combination air cleaner of the same design as on the D-35 and KDM-46 tractor Diesels.

The lubrication is combination splash and pressure, with the pressure supplied by a gear-type oil pump. The oil is double-filtered in a KDM-46 filter which uses KDM-46 filter cartridges.

A single-plunger fuel pump is planned for this series of Diesels (for the one-, two-, and three-cylinder engines). The six- and eight-cylinder engines are fitted with a pair of single-plunger pumps, and the twelve-cylinder engine is fitted with three interlinked single-plunger pumps.

Until the production of single-plunger fuel pumps is organized, NTN1-8.5 pumps made by the Noginsk Fuel Equipment Plant can be used on the two- and three-cylinder engines. When installing the NTN1-8.5 pump on the two-cylinder Diesel, two pairs of plungers are removed and put aside; when installing this pump on the three-cylinder Diesel, one pair of plungers is removed and the standard camshaft is replaced by a special one with three cams.

The one-cylinder Diesel is equipped with a fuel pump whose plunger is moved by a special cam on the camshaft.

The single-plunger fuel pump is equipped with an all-speed centrifugal governor and a gear-type pump, joined together as a unit and driven by the camshaft timing gear. The pump is attached to the engine in the same way as the NTN1-8.5 pump, so that one pump can easily be replaced by the other.

The fuel is strained before entering the fuel pump by a standard fine filter which uses the filter cartridge of the KDM-46 Diesel.

All Diesels are equipped with identical plunger injectors.

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The cooling systems of these Diesels are hermetic, operating under pressure developed by the centrifugal water pump. The water pump shaft is fitted with a fan; driven by a V-belt, for cooling the radiator. There is a thermostat in the cooling system.

Gasoline starting motors, the same as those used on the tractor Diesels, are used on this series of engines. A device for reducing pressure is provided to make it easier to turn over the engine with the starting motor.

Active planning of one-, two, and three-cylinder Diesels was carried on and experimental models built concurrently with the discussion of general questions related to the whole series of Diesels. The two-cylinder Diesel passed preliminary tests and has been put into series production at the Andizhan Plant of the Ministry of Construction and Road Machine Building.

To determine the degree of unification of over-all size and weight indexes, design components, and other factors, the preliminary technical planning with the necessary calculations for four-, six, and twelve-cylinder engines has been completed.

The next steps in organizing the production of these Diesels are to carry out research and perfect the working process and design elements on models of the one-, two, and three-cylinder engines, to determine their wear resistance, to make them capable of operating, 2,000-3,000 and more hours without repair, and to organize the production of the engines.

The project for the development of a series of Diesels for construction and road machines was directed by N. V. Pul'manov.

Others taking part in the project were engineers, designers, and analysts of the power engineering laboratory of VNIISTroydormash; A. I. Skokan, M. D. Posvyanskly, B. M. Ivanov, B. N. Velichenko, I. S. Nikitin, K. M. Molchanov, and other; and also the collectives of the Andizhan Plant and the experimental plant of VNIISTroydormash.

Table 1. Power Range of Diesel Series and Corresponding Road and Construction Machines

(All Diesels in the series have a stroke of 170 millimeters; all but the 12-cylinder Diesels have a bore of 125 millimeters.)

Specifications of One-Cylinder Engine

Horsepower	14 at 1,000 rpm 17 at 1,200 rpm 21 at 1,500 rpm
Weight (kg) (dry)	460
Length (mm)	685
Width (mm)	620
Height (mm)	1,105

The above engine is designed to power the following machines: 3-5 ton tandem rollers; mobile bitumen pumps, asphalt concrete surface heaters, narrow-gauge motor locomotives, asphalt mixer drying drums, open-pit mining excavators, wheel-mounted prime movers, mobile cranes for laying and removing rails, mobile asphalt mixers, vibrator-action finishers, ditching machines, concrete-vacuuming machines, fork lifts, light movable two-rope cableways, motor cars, mobile electric power stations, mobile electric welding aggregates, mobile compressor units, and concrete spreaders.

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Specifications of Two-Cylinder Engine

Horsepower	28 at 1,000 rpm 34 at 1,200 rpm 42 at 1,500 rpm
Weight (kg) (dry)	750
Length (mm)	835
Width (mm)	790
Height (mm)	1,150

The above engine is designed to power the following machines; ditching machines, transverse-boom multiple-bucket excavators, transverse-boom open-pit mining excavators, three-drum rollers, mobile electric power stations, bitumen heater-circulators, hopper-type concrete spreaders, concrete finishers, winches, truck-mounted concrete mixers, mobile crushing and sorting devices, asphalt pavers, screwconveyer concrete spreaders, light motor graders, medium motor graders, truck-mounted bitumen distributors, mobile compressor units, aggregates for mixing and applying paving materials at the construction site, asphalt concrete mixers, self-propelled track hoists, fork lifts, multiple-bucket loaders, self-propelled pneumatic feeders, movable two rope cableways, standard-gauge motor locomotives, narrow-gauge motor locomotives, motor-cars, concrete-vacuumizing machines, electric welding units.

Specifications of Three-Cylinder Engine

Horsepower	42 at 1,000 rpm 51 at 1,200 rpm 63 at 1,500 rpm
Weight (kg) (dry)	850
Length (mm)	980
Width (mm)	790
Height (mm)	1,150

The above engine is designed to power the following machines: 0.25-cubic-meter capacity excavators, peat-extracting machines, irrigation-canal diggers, ditching machines, transverse-boom multiple-bucket excavators, heavy rollers, pumps for bitumen aggregates, rail-mounted concrete pavers, standard-gauge motor locomotives, narrow-gauge motor locomotives, mobile electric power stations, mobile compressor units, grader-elevators, asphalt-mixing devices, machines for leveling beds for concrete roads, excavatorcranes mounted on pneumatic tires.

Specifications of Four-Cylinder Engine

Horsepower	56 at 1,000 rpm 68 at 1,200 rpm 84 at 1,500 rpm
Weight (kg) (dry)	1,100
Length (mm)	790
Height	1,185

The above engine is designed to power the following machines: ditching machines, peat extraction machines, 10-ton cranes mounted on pneumatic tires, asphalt mixers, machines for mixing paving materials at the construction site, tandem rollers, power tampers, cranes for laying and loading tracks, machines for laying rails, power equipment-moving platforms, fork lifts, heavy two-rope movable cableways, standard-gauge motor locomotives, narrow-gauge motor locomotives, motor cars, mobile electric power stations, mobile compressor units, electric welding units.

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Specifications of Six-Cylinder Engine

Horsepower	85 at 1,000 100 at 1,200 125 at 1,500
Weight (kg) (dry)	1,600
Length (mm)	1,510
Width (mm)	850
Height	1,220

The above engine is designed to power the following machines: 0.5-cubic-meter capacity excavators, heavy motor graders, mobile crushing units, cranes running on crawlers and on pneumatic tires, ditching machines, prime movers for scrapers, towed rippers, aggregates for mixing and applying paving materials at the construction site, asphalt-concrete mixers, rotary towed mills, rotary snow removers, standard-gauge motor locomotives, narrow-gauge motor locomotives, crushing-sorting aggregates, concrete vacuumizing machines, pipe-cleaning machines, mobile electric power stations, mobile compressor units.

Specifications of Eight-Cylinder Engine

Horsepower	115 at 1,000 rpm 140 at 1,200 rpm 170 at 1,500 rpm
Weight (kg)	2,000
Length (mm)	1,700
Width (mm)	1,100
Height (mm)	1,100

The above engine is designed to power the following machines: one-cubic meter capacity excavators, 25-ton capacity railroad cranes, rotary snow removers, wheel-mounted bulldozers, single-axle prime movers for 15-cubic-meter capacity scrapers, standard-gauge motor locomotives, narrow-gauge motor locomotives, mobile electric power stations.

Specifications of First 12-Cylinder Engine:

Bore (mm)	130
Horsepower	200 at 1,000 rpm 240 at 1,200 rpm 300 at 1,500 rpm
Weight (kg)	3,300
Length (mm)	2,100
Width (mm)	1,100
Height (mm)	1,100

Specifications of Second 12-Cylinder Engine:

Bore (mm)	130
Horsepower	240 at 1,000 rpm 288 at 1,200 rpm 360 at 1,500 rpm
Weight (kg)	3,400
Length (mm)	2,100
Width (mm)	2,100
Height (mm)	1,100

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Both the above engines are designed to power the following machines: 2-, 3-, and 4-cubic-meter capacity excavators, 50-ton capacity railroad cranes, wheel-mounted bulldozers, prime movers for 25-cubic-meter capacity scrapers, road mills, narrow-gauge motor locomotives, mobile electric power stations, 50-ton capacity crawler-mounted cranes, prime movers for heavy earth-hauling trailers, standard-gauge motor locomotives.

Table 2. Comparative Design and Performance Indexes of Proposed Series of Diesels and Existing Tractor Diesels

Index	Series			
	MS and DM	KDM-46	D-54	D-35
Rpm at maximum hp	1,200	1,000	1,300	1,400
Power in one cylinder (hp)	17	23.2	13.5	9.25
No of cylinders	1,2,3,4,6,8, and 12	4	4	4
Cylinder bore (mm)	125	145	125	100
Piston stroke (mm)	170	205	152	130
Displacement of one cylinder (liters)	2.09	3.38	1.86	1.02
Type combustion chamber	Precombustion	Precombustion	Turnover	Turnover
Compression ratio	16	15.5	16	17
Specific minimum fuel consumption (gr effective hp)	220	205-220	220	220-225
Mean efficient pressure at maximum hp (kg/sq cm)	6.1	6.2	5.0	5.82
Average piston speed (meters/sec)	6.8	6.84	6.6	6.05
Hp/liter of displacement	8.14	6.86	7.26	9.05
Hp/liter rpm	0.00679	0.00686	0.00559	0.00646
Piston area (sq cm)	122.5	165.0	122.5	78.5
Piston power (hp/sq dm)	13.6	14.1	11.0	11.8

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Table 3. Weight and Size Indexes of Diesels

<u>Index</u>	<u>T-111</u>	<u>T-112</u>	<u>T-113</u>	<u>T-114</u>	<u>T-116</u>	<u>T-118</u>	<u>TU-12</u>	<u>KDM-46</u>	<u>D-35</u>	<u>D-54</u>	<u>2-D-6</u>
Engine weight (kg)	460	750	850	1,100	1,600	2,000	3,300	2,000	780	1,270	1,250
Specific weight (kg/hp)	27.0	22.0	17.0	16.2	16.0	14.3	13.8	21.5	21.1	23.6	8.35
Liter weight (kg/liter)	220	180	136	132	128	120	132	148	191	171	65.4
Over-all dimensions (mm)											
Length	635	835	980	1,100	1,510	1,710	2,100	1,843	1,271	1,538	2,024
Width	620	790	790	790	850	1,100	1,100	984	674	815	775
Height	1,105	1,150	1,150	1,185	1,220	1,100	1,100	2,005	1,303	1,183	1,125

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